

RF DATA COMMUNICATIONS LINK FOR SETTING ELECTRONIC FUZES

BACKGROUND OF THE INVENTION

5 This invention relates generally to a communications link between a fuze setter and a fuze, and more specifically to an improved fuze setter capable of transmitting a magnetic inductive power carrier signal and a separate high speed data signal.

10 Multifunctional electronic fuzes for artillery and other projectiles are generally known in the art. For example, US 5497704 teaches a multifunctional magnetic fuze, the entire disclosure of which is incorporated herein by reference. Multifunctional electronic fuzes may be programmed to trigger detonation of a projectile upon the satisfaction of various parameters, such as time-to-burst, turns-to-burst, height of burst, proximity, and the like.

15 Fuzes may be programmed by a fuze setter before the projectile is launched. Generally, fuzes are powered up and set or programmed using a magnetic inductive link between the fuze and the fuze setter. US 5497704 and US 6176168 disclose methods of powering and setting a fuze using a fuze setter. US 6176168 is incorporated herein by reference.

20 In transferring power to a fuze absent a physically conductive connection, a magnetic waveform or power carrier may be inductively communicated from the fuze setter to the fuze. The inductive power carrier signal can be converted into an electrical current by a magnetic transducer within the fuze. The current may be used to charge the power supply of the fuze and thereby provide the fuze with operational power during its mission.

25 Fuze setting data, such as calibration data and parameter data, may also be transferred to the fuze over the magnetic inductive link. The power carrier signal may be modified in order to communicate setting data to the fuze. This is generally accomplished by modulating the magnetic waveform.

30 One method of communicating the fuze setting data utilizes a resonance coupling between the fuze and the fuze setter, and pulse or amplitude modulation of the power carrier signal. The modulated signal may transmit digital data bits via amplitude

adjustment over a predetermined period of time. For example, a data bit may be transmitted every millisecond. Specifically, a 250 microsecond low amplitude signal followed by a 750 microsecond higher amplitude signal may represent a zero, whereas a 500 microsecond low amplitude signal followed by a 500 microsecond higher amplitude signal may represent a one.

The amplitude modulated signal thus includes both the power transmission and the data transmission signals. The fuze is able to translate the modulated signal and extract the usable fuze setting data. This method allows the magnetic waveform to remain at full amplitude throughout nearly the entire transmission period, thereby providing high efficiency in the power transmission and full power transfer to the fuze in a short period of time. However, because of the narrow bandwidth of the modulated signal, transmission of the setting data is relatively slow.

Another method of communicating fuze setting data utilizes a transformer coupling between the fuze and the fuze setter, and pulse modulation of the power carrier. With pulse modulation, the transformer coupled power signal from the fuze setter to the fuze is switched on and off in order to communicate the setting data. This method allows for a faster setting data transmission rate at the cost of reduced power transfer to the fuze.

Prior art fuze setting methods using magnetic inductance have generally been sufficient for the transfer of conventional fuze setting information. However, prior art methods are not capable of satisfying the high data transfer rates required to program newer fuzes that utilize GPS data within desirable time constraints. Data transmission bit rates of 100,000 bits/second or more are desirable. A GPS fuze may require 30,000 bits of information or more for proper setting. Further, it is generally desirable to transfer power and setting information to a fuze as quickly as possible.

There remains a need for a device capable of transmitting a power carrier and full fuze setting data to a projectile fuze in a short period of time. Desirably, the setting data transmitted to the fuze may be checked by reverse transmission of the data received by the fuze to the fuze setter.

All US patents and applications and all other published documents mentioned anywhere in this application are incorporated herein by reference in their entirety.

Without limiting the scope of the invention, a brief summary of some of the embodiments of the invention is set forth below. Additional details of the summarized embodiments of the invention and/or additional embodiments of the invention may be found in the Detailed Description of the Invention below.

5 A brief abstract of the technical disclosure in the specification is provided as well only for the purposes of complying with 37 C.F.R. 1.72. The abstract is not intended to be used for interpreting the scope of the claims.

BRIEF SUMMARY OF THE INVENTION

10 It is an object of the invention to utilize the efficiencies of magnetic resonance coupling in transferring power to a fuze.

 It is an object of the invention to utilize a radiatively coupled data link for high speed communication of fuze setting data to a fuze.

 It is an object of the invention to provide power transfer and setting data
15 transfer to a fuze utilizing hardware that may already be contained within a fuze.

 It is an object of the invention to provide a high speed data communication link that provides a greater amount of setting data to the fuze over a predetermined period of time.

 It is an object of the invention to provide a high speed data
20 communication link that allows for faster firing rates.

 In one embodiment, the invention comprises a system for programming a fuze, wherein a fuze having a receiver and a fuze setter having a transmitter are provided. Pre-launch fuze setting data may be transmitted from the transmitter to the receiver via an electromagnetic signal selected from a group consisting of the audio,
25 ultrasonic, infrared, RF, visible and UV bands of the electromagnetic spectrum.

 In another embodiment, the invention comprises a system for programming a fuze, wherein a fuze having a radio frequency receiver and a fuze setter having a radio frequency transmitter are provided. Pre-launch fuze setting data may be transmitted from the radio frequency transmitter and received by the radio frequency
30 receiver. Fuze setting data may be encoded into a radio frequency carrier using frequency shift keying.

In another embodiment, the invention comprises a fuze setter. The fuze setter may include a controller, a magnetic inductive portion for generating a magnetic waveform output, and a radiative transmitter portion for generating a radiative data signal output containing fuze setting data.

5 In another embodiment, the invention comprises a method of setting a projectile fuze. A fuze having a radio frequency receiver and a fuze setter having a radio frequency transmitter may be provided. Fuze setting data may then be transmitted from the radio frequency transmitter to the radio frequency receiver.

10 These and other embodiments which characterize the invention are pointed out with particularity in the claims annexed hereto and forming a part hereof. However, for a better understanding of the invention, its advantages and objectives obtained by its use, reference should be made to the drawings which form a further part hereof and the accompanying descriptive matter, in which there are illustrated and described various embodiments of the invention.

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BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

A detailed description of the invention is hereafter described with specific reference being made to the drawings.

20 Figure 1 shows a block diagram of a fuze setter and a fuze depicting an embodiment of the invention.

Figure 2 shows a block diagram depicting another embodiment of the invention.

Figure 3 shows another block diagram of yet another embodiment of the invention.

25 Figure 4 shows an embodiment of the invention according to Figure 3.

Figure 5 shows a block diagram of a fuze setter and a fuze in more detail.

Figure 6 shows an embodiment of a transmitter.

Figure 7 shows an embodiment of a receiver.

Figure 8 shows an embodiment of a transceiver.

30 Figure 9 shows waveform depictions of a modulation signal and an IF output.

Figure 10 shows waveform depictions of a modulation signal and an IF output.

DETAILED DESCRIPTION OF THE INVENTION

While this invention may be embodied in many different forms, there are described in detail herein specific embodiments of the invention. This description is an exemplification of the principles of the invention and is not intended to limit the invention to the particular embodiments disclosed.

For the purposes of this disclosure, like reference numerals in the figures shall refer to like features unless otherwise indicated.

Referring to Figure 1, in one embodiment the invention comprises a high speed radiative data transfer link 10 between a fuze setter 12 and a fuze 20. Fuze setting data may be transmitted by a transmitter 14 within the fuze setter 12, and received by a receiver 22 within the fuze 20.

Fuze setting data may comprise all relevant information required by a fuze to complete a mission. This data may include a timer startup instruction, a timer calibration signal, arming conditions, time-to-burst, distance or turns-to-burst, height of burst, proximity to target including land, air and water proximity, composition of target, maximum mission time, impact instruction, delay from impact, fuze mode selection, burst delay, sterilization conditions, current GPS data, target GPS data, and the like.

Fuze setting data may be carried by a radiative data signal 10 comprising a modulated carrier signal transmitted from a transmitter 14 to a receiver 22.

Appropriate circuitry within the fuze 20 may decipher the desired fuze setting data from the modulated carrier signal. Data transmission over an inventive radiative data link 10 between a fuze setter 12 and a fuze 20 may be accomplished using frequencies from the audio, ultrasonic, infrared, radio-frequency, visible light and/or ultraviolet bands of the electromagnetic spectrum. The transmitter 14 and receiver 22 may be selected appropriately to be capable of transmitting and receiving data using the selected bands. For example, if audio transmission is selected, the transmitter 14 may comprise an electrodynamic speaker, and the receiver 22 may comprise a microphone. If radio frequency transmission is selected, the transmitter 14 may comprise an RF transmitter, and the receiver 22 may comprise an RF receiver.

In another embodiment, as shown in Figure 2, the fuze setter 12 may include a transceiver 14, and the fuze 20 may include a transceiver 22. Each transceiver 14, 22 may be capable of transmitting and receiving a data signal. The use of transceivers allows a talkback 10a communication of data from the fuze 20 to the fuze setter 12 in order to provide a check function to assure proper and complete transfer of setting data from the fuze setter 12 to the fuze 20.

The fuze setter transceiver 14 may first be set to transmit, and the fuze transceiver 22 may be set to receive. A radiative data signal 10 that includes fuze setting data may be communicated from the fuze setter transceiver 14 to the fuze transceiver 22, and a logic circuit 24 within the fuze 20 may decode the fuze setting data.

The fuze transceiver 22 may then be set to transmit, and the fuze setter transceiver 14 may be set to receive. Switching of the transceiver functions may be accomplished by any appropriate method. For example, the logic circuit 24 of the fuze 24 may be programmed to switch the fuze transceiver 22 from the receive function to the transmit function upon receiving a complete set of fuze setting data. Similarly, the controller 16 of the fuze setter 12 may switch the setter transceiver 14 from the transmit function to the receive function upon transmitting a complete set of fuze setting data.

With the fuze transceiver 22 set to transmit and the fuze setter transceiver 14 set to receive, a “talkback” signal 10a may be communicated from the fuze transceiver 22 to the fuze setter transceiver 14 to verify the setting data originally received by the fuze 20. The talkback signal 10a may include all of the relevant fuze setting data, a portion of the fuze setting data, or may comprise a separate signal not containing actual setting data but a related data set that allows the fuze setter 12 to determine whether or not the fuze 20 received the proper setting data. If an error occurred in the original data transmission from the fuze setter 12 to the fuze 20, the fuze programming operation may be repeated.

In another embodiment, the invention comprises a high speed radiative data transfer link 10 and a magnetic inductive power link 26 between a fuze setter 12 and a fuze 20. Examples of this embodiment are shown in Figures 3 and 4.

A magnetic inductive power link 26 utilizing resonance coupling may be used to transfer power to the fuze 20. A power transmitter 18 portion of the fuze setter

12 may transmit a magnetic waveform or power carrier signal to be received by a power receiver 28 within the fuze 20. A magnetic inductive power link 26 provides operational power to the fuze 20.

As shown in Figure 4, the power transmitter 18 may include a transmitter coil 18a. The transmitter coil 18a may be inductively coupled to the power receiver 28 of the fuze 20. Thus, the transmitter coil 18a is desirably located proximal to the power receiver 28 during fuze setting. The power receiver 28 may comprise a magnetic transducer, and may thus convert the magnetic power waveform into useable electrical power.

In instances where the fuze 20 does not include a separate onboard power supply, such as a battery, electrical power received by the power receiver 28 may be used to charge onboard power storage devices, such as capacitors, and to operate all electrical circuits within the fuze 20. Thus, in some embodiments, it is desirable to provide a power transmission from the fuze setter 12 to the fuze 20 for a predetermined period of time before transmitting the setting data to allow all electrical systems within the fuze 20 to power up. For example, data transmission from the data transmitter 14 may be arranged to begin after an initial power-up period, such as a half-second initial power transmission.

Fuze setting data may be transferred from the fuze setter 12 to the fuze via a high speed radiative data transfer link 10 as described above. The fuze 20 and fuze setter 12 may be arranged to check the fuze setting data transmitted using an appropriate talkback signal 10a.

In some embodiments, the fuze setter 12, or the power transmitter 18 and data transmitter 14 of the fuze setter 12, may be physically positioned directly above a projectile during fuze setting. The radiative data signal 10 may be arranged to pass through the center or a central portion of a transmitter coil 18a and a power receiver 28 coil, or along a central axis of a transmitter coil 18a and a power receiver 28 coil.

Figure 5 shows a more detailed depiction of a fuze 20 and a fuze setter 12. Power for the fuze 20 may be inductively transmitted over a magnetic inductive power link 26 from a power transmitter 18 in the fuze setter 12 and received by a power receiver 28 within the fuze 20. The power receiver 28 may comprise a multi-functional magnetic receiver as may be found in fuzes such as the M782 Multi-Option Fuze for

Artillery (MOFA), available from Alliant Techsystems, Inc. The multi-functional magnetic receiver 28 may receive the power carrier waveform and transduce the magnetic waveform into electrical power. Further, the multi-functional magnetic receiver 28 may be used to detect other magnetic fields during a mission, such as the Earth's magnetic field, to provide the fuze with turns-counting capabilities as disclosed in US 5497704.

The data transceiver 14 of the fuze setter may transmit fuze setting data over a radiative data link 10 that may be received by a data transceiver 22 on board the fuze 20. The received data signal may be filtered and decoded, as shown in block 40, to extract the fuze setting parameters, which may be provided to the logic processor of the fuze 20. In some embodiments, the filtering and decoding devices 40 may be incorporated into a data transceiver 22.

Digital fuze setting data may be combined with a carrier signal to be transmitted from the fuze setter 12 to the fuze 20 using any suitable method. For example, frequency shift keying may be used to transmit digital data using two different analog carrier frequencies that represent zero and one. The signals may be received on board the fuze 20 by the data transceiver 22 and filtered and decoded as described above.

Figure 6 shows an embodiment of a transmitter 14 that may be used to transmit a radiative data signal 10 in a frequency shift keying format. Fuze setting data in digital form may comprise a digital serial data stream 42. The digital data stream 42 may be converted into an analog modulation signal 44 by a level shifting device 32.

In one embodiment, a level shifter 32 may comprise a first digital-to-analog converter 34, a second digital-to-analog converter 36 and a switch 38. The digital data stream 42 may be used to control the output of the level shifter 32 by switching between the first DAC 34 and the second DAC 36 according to the digital bits of the digital data stream 42. Desirably, the first DAC 34 may have a first output voltage and the second DAC 36 may have a second output voltage. Thus, the modulation signal 44 or output of the level shifter 32 may comprise an analog signal, such as a square wave, having two different voltages or levels.

The modulation signal 44 may be used by a modulator 50 to create the radiative data signal 10. The modulator 50 may generate a carrier waveform and

modulate the frequency of the carrier waveform according to the modulation signal 44 received from the level shifter 32. The final radiative data signal 10 may be transmitted to the fuze 20 by any appropriate method. For example, if the radiative data signal 10 comprises a radio frequency signal, an antenna 52 may be used.

5 Figure 7 shows an embodiment of a receiver 22 that may be used to receive a radiative data signal 10. The incoming radiative data signal 10 may be processed by a demodulator 54, wherein the carrier signal may be removed from the radiative data signal 10, and the resulting intermediate frequency analog signal 46 may be output. The intermediate frequency analog signal 46 may be filtered by a low pass
10 filter 58 to remove any extraneous signals.

 In some embodiments, the filtered intermediate frequency analog output 46 may be used by a logic circuit or processor directly. In other embodiments, the intermediate frequency analog output 46 may be converted into the digital serial data stream 42 by a signal conditioning device 60, such as an analog-to-digital converter.

15 Figure 8 depicts a transceiver 66 that may be arranged to act as either the transmitter 14 or the receiver 22. Transceivers 66 may be used in both the fuze setter 12 and the fuze 20. The use of transceivers 66 allows for a talkback signal 10a to be transmitted from the fuze 20 to the fuze setter 12 to verify the accuracy of the fuze setting data received by the fuze 20, as previously described herein. Components of the
20 transmitting portion of the transceiver 66 are analogous to transmitter components as described in Figure 6. Components of the receiving portion of the transceiver 66 are analogous to receiver components as described in Figure 7. A transceiver 66 further comprises a mode switch 56 for switching between transmit and receive functions.

 An example of a commercially available transceiver 66 is the SureLink
25 915A-FM RF Transceiver Module which uses the XE 1202 UHF Transceiver available from Xemics USA, Inc.

 In laboratory testing using a MOFA transceiver acting as the transmitter 14 and a MOFA transceiver and Radome acting as the receiver 22, the potential for data transmission rates exceeding 1,000,000 bits/second has been demonstrated. In various
30 embodiments, the invention may provide data transmission rates exceeding predetermined amounts. For example, one embodiment of the invention may allow at least 1,000 bits/second to be transmitted from the transmitter to the receiver. Other

embodiments may allow data transfer rates of at least 70,000 bits/second and at least 500,000 bits/second. The use of such high bit rates allows for full fuze setting and a complete talkback verification in as little as $1/10^{\text{th}}$ of a second or less, depending on the amount of fuze setting data required. The actual data transmission limitations are
5 dependent upon the actual bandwidth used in transmitting the radiative data signal 10.

Figure 9 shows example waveforms of a modulation signal 44 and an IF output signal 46 generated when using a MOFA transceiver acting as the transmitter 14 and a MOFA transceiver and Radome acting as the receiver 22.

Figure 10 shows another example of waveforms of a modulation signal
10 44 and an IF output signal 46.

Fuzes 20 currently in existence may already include an RF transceiver for functions other than to receive and talkback setting data. Generally, such fuzes are charged and set through magnetic inductance. When utilizing an embodiment of the invention described herein wherein setting data is transmitted across a radio frequency
15 data link and power is transmitted across a magnetic inductive link, modifications to the fuze and fuze setter may be minimal. In some cases, the only hardware modification required may be to equip a fuze setter with a radiative transmitter 14.

Desirably, the transmitter 14 of the fuze setter 12 will be in proximity to the receiver 22 of the fuze 20 during transmission of the radiative data signal 10. In
20 some embodiments, the transmitter 14 may be no farther than six inches away from the receiver 22 during fuze setting.

The invention also relates to a method of setting a fuze using a radiative data signal. Generally, a fuze having a receiver and a fuze setter having a transmitter may be provided. Fuze setting data may be transmitted from the transmitter to the
25 receiver via an electromagnetic signal selected from a group consisting of the audio, ultrasonic, infrared, RF, visible and UV bands of the electromagnetic spectrum.

In some embodiments, the receiver may comprise an RF receiver, the transmitter may comprise an RF transmitter, and the fuze setting data may be transmitted via a radio frequency carrier signal. The radio frequency carrier signal may
30 comprise a frequency modulated signal comprising two frequencies, the frequency modulated signal transmitting digital data.

In some embodiments, the fuze may further include a transmitter, the fuze setter may further include a receiver, and the fuze setting data received by the fuze may be verified by a reverse transmission from the fuze back to the fuze setter.

5 In some embodiments, the fuze setter may further comprise an inductive power transmitter, and the fuze may further comprise an inductive power receiver magnetic transducer. Thus, operational power may be inductively transferred to the fuze immediately before and during fuze setting.

10 Thus, an inventive method of setting a fuze may include positioning the inductive power transmitter of the fuze setter in proximity to the inductive power receiver of the fuze and transmitting a power carrier. After an initial charging period, fuze setting data may be transmitted from the transmitter of the fuze setter to the receiver of the fuze. Data transmission may be accomplished by sending a frequency modulated carrier signal. A logic circuit within the fuze may decode the transmission and extract the fuze setting data. The fuze transmitter may then transmit a signal back to
15 the receiver of the fuze setter for verification of the accuracy and completeness of the fuse setting data received.

The above disclosure is intended to be illustrative and not exhaustive. This description will suggest many variations and alternatives to one of ordinary skill in this art. All these alternatives and variations are intended to be included within the
20 scope of the claims where the term "comprising" means "including, but not limited to". Those familiar with the art may recognize other equivalents to the specific embodiments described herein which equivalents are also intended to be encompassed by the claims.

Further, the particular features presented in the dependent claims can be combined with each other in other manners within the scope of the invention such that
25 the invention should be recognized as also specifically directed to other embodiments having any other possible combination of the features of the dependent claims. For instance, for purposes of claim publication, any dependent claim which follows should be taken as alternatively written in a multiple dependent form from all prior claims which possess all antecedents referenced in such dependent claim if such multiple
30 dependent format is an accepted format within the jurisdiction (e.g. each claim depending directly from claim 1 should be alternatively taken as depending from all previous claims). In jurisdictions where multiple dependent claim formats are restricted,

the following dependent claims should each be also taken as alternatively written in each singly dependent claim format which creates a dependency from a prior antecedent-possessing claim other than the specific claim listed in such dependent claim below.

- 5 This completes the description of the preferred and alternate embodiments of the invention. Those skilled in the art may recognize other equivalents to the specific embodiment described herein which equivalents are intended to be encompassed by the claims attached hereto.